C. AESTHICS IN PRESENTATONS

"It is sometimes difficult to differentiate models used for the creation of pieces of art from those used with scientific purpose in mind," (Fishwick, 1999). Images created from models used for a technical or scientific purpose are predicated on unambiguously transferring their message without regard to their appearance. "The purpose of art, on the other hand, is to permit some ambiguity with the hopes of causing the viewer or listener to reflect upon the modeled world," (Fishwick, 1999). Should ambiguous elements be removed or added to make an image more visually pleasing? Improvements presented in this thesis for FNMOC JMV display package give navy users the choice. Warfighters can specify how much background detail they find useful. Forecasters can turn on and off or contour background features depending on the mission, objective, area, or simply level of detail desired.

In choosing coloring schemes for the background imagery produced by this thesis three tenets were followed. These were: (1) the requirement to differentiate elevation difference with color, (2) the requirement to make the imagery as naturally realistic as possible (darker green for valleys, shades of white and gray for colder regions, etc), (3) the requirement that the imagery met a subjective test by the programming group of being visually appealing.

II. JOINT METOC VIEWER OVERVIEW

A. SYSTEM DESIGN AND ARCHITECTURE

Fleet Numerical Meteorology and Oceanogarphy Center's (FNMOC's) Joint METOC Viewer (JMV) (FNMOC, 1999) is cross platform compatible. It runs in both the Windows and Unix environments. JMV's performance, like other government of the shelf software (GOTS) and commercial off the shelf software (COTS), is hardware dependent. The baseline installation of the software runs adequately on even older machines (Pentium II 200 Mhz) with a moderate amount of memory (~64 MB), and disk space (~1 GB free), and a 56k modem. Its performance is enhanced with the addition of improved hardware components, and is enhanced exponentially when tied to a high-speed network.

B. JMV 3.1 CAPABILITIES

1. System Overview

As shown in Figure 1, JMV displays METOC data and information from different sources in traditional formats used by forecasters. General meteorologic formats include maps containing contours, plots, and other weather depictions of METOC variables, cross-sections of ocean and atmospheric variables, plots of vertical variation of METOC variables such as bathythermographs and atmospheric soundings, time series, and time sections depicting measured or forecast changes in METOC variables at selected points. Overlays of weather depictions on satellite imagery further facilitate analysis of

environmental conditions. Animation of several of these products enhances the

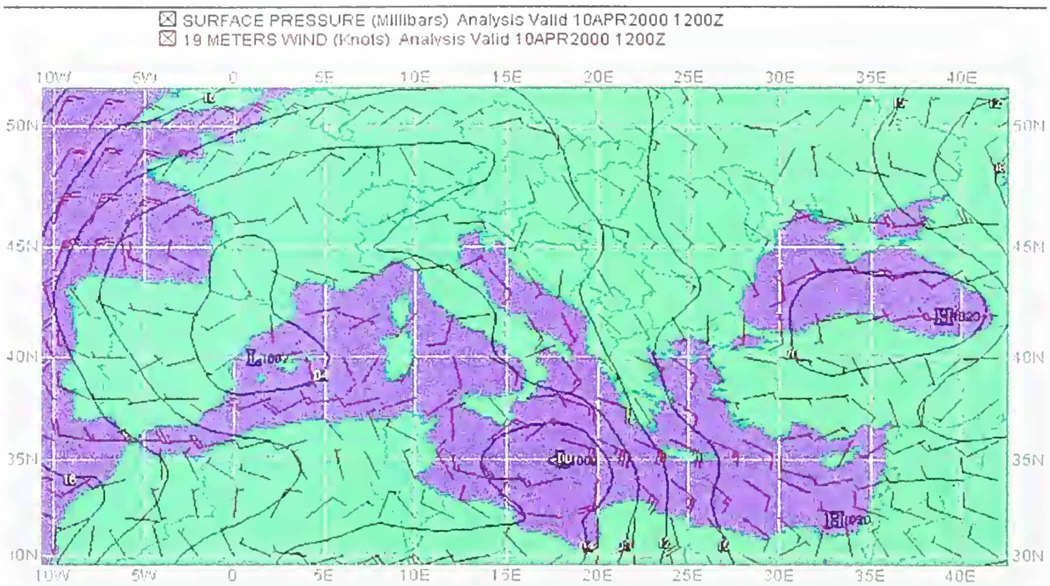

Figure 1. Sample JMV display of NOGAPS Surface Pressure and 19 m Winds over Europe and the Mediterranean Sea.

forecaster's ability to understand the dynamic aspects of the METOC changing environment.

2. Current System Functionality

JMV is a stand-alone viewer for METOC data. It may be used in conjunction with the METCAST Client segment, which can automate the downloading of data required by JMV users. It also has the capability to download data from "thumbnails" posted on web pages. A "thumbnail" represents a specially formatted file containing data to be displayed in JMV. JMV may also be used to display data provided by a local user or program.

Tables 1 lists the primary operational capabilities of JMV prior to the work done FOR this thesis. Individual functions are delineated and explained in the tables and they also serve as both as a reference and as context for integrating digital terrain into the viewer.

Table 1. JMV Statement of Functionality, FNMOC, 1999

Display and Annotate Charts of METOC Data. JMV can display scalar METOC data as contour charts, color-filled and/or patterned areas, or both. Vector data may be presented as wind barbs, arrows, or streamlines. Observational data may be presented as station models or simple location indicators. The location indicators, when clicked, show data views tailored to the data type (e.g. raw reports for METARs, Skew-T Log P diagrams for upper air reports). Three-dimensional scalar data may be shown as horizontal slices (contour charts), vertical cross-sections, or vertical profiles at selected points. JMV also provides a complete set of annotation tools, which allow the user to embellish a chart with weather symbols, text, and a variety of line types (e.g. weather front representations, labeled lines, etc.). Objects drawn on the chart may be resized and their shapes may be modified. When preparing for animation, objects may be drawn on the first chart and moved and/or reshaped for subsequent forecast hours, so that the drawn objects are animated along with the charts.
Satellite Imagery Display. JMV can display geolocated satellite imagery, and provides a suite of tools to enhance imagery. Multiple images may be displayed simultaneously. Satellite imagery may be overlaid with METOC charts and drawn objects.
Ship Route Display. This module allows users to input and graphically display and edit ship tracks worldwide. Any meteorological and oceanographic product available (including drawings) can be overlaid on a track. The display can be incremented in one-hour intervals to show a vessel progressing along its track. Overlaid meteorological and oceanographic products are interpolated to show one-hour increments in order to progress smoothly with the vessel track.
Extratropical Winds and Seas Warnings. This module is used to build winds and sea warning areas while overlaying the actual weather charts, greatly simplifying the process and reducing the possibility of error. The graphics are converted to text in message format for transmission.
Tropical Cyclone Warning Display. This function ingests information on tropical cyclones worldwide. These tropical systems can then be displayed in conjunction with any other product available to JMV. Standard display features include forecasted positions, wind radii, intensity, danger areas, and movements in standard warning format. When used in conjunction with the Ship Route feature, the closest point of approach (CPA) is automatically calculated. Tropical cyclone positions and intensities can display at non-standard tropical forecast times.

Table 1 (Continued). JMV Statement of Functionality, FNMOC, 1999

Slide Show. Slide Show is a tool to build, display, and save briefing slides. An individual slide can contain up to five products per chart, including color fills and drawings. A user can control how the charts are displayed during the presentation. When the underlying data for a slide show updates, the entire presentation can be updated by choosing the build button without recreating the entire show. The user may also print the entire slide show to a printer or save it in hypertext Markup Language (HTML) for viewing on a web page.
Range and Bearing Tool. In Range and Bearing mode, rhumb line distances and bearing are easily calculated with the click of a mouse button. Additional points give the distance and bearing from the last two points as well as a cumulative distance and bearing from the original point.
Export Images. JMV can export images for use in other applications. Options include BMP, JPEG, and GIF image formats, and direct conversion to an HTML format.
Animation. JMV allows automated animation of METOC charts. The user simply designs one chart containing the data to be displayed for a single forecast hour, then clicks a button to perform the animation. The system automatically retrieves the same data for all of the other forecast hours selected, then produces the individual frame for each forecast hour. User-drawn objects (such as a Horizontal Weather Display) may be produced by a user and tied to the appropriate forecast hours, so that they are animated along with the rest of the charts.
Data Thinning. JMV can apply data thinning for observation data to improve the readability of charts. The amount of data thinning applied is user-selectable, and data thinning may also be toggled off completely.
Display Configurations. Station Model and Wind Barb displays are easily configured to user specifications.
Font Sizes. The User may select the font sizes for product labels, contour labels, Ship track labels, Storm track labels, and OPARS track labels.
Contour Labeling. Center values for all highs and lows are displayed. Contour lines are also automatically labeled.
OPARS. JMV imports and displays aircraft flight paths created with Optimum Path Aircraft Routing software. The advantage of this feature is that forecast conditions can be overlaid on the flight path.
Four Panel Display. This function enables four charts to be displayed simultaneously on the screen. Additionally, the four-panel display can print to a single sheet of paper.
Online Help. JMV is supplied with detailed, web browser-based online help.

Prior to results arising from this thesis, geo-spatial information in the viewer was restricted to low resolution coastlines and political boundaries. Coastlines and political boundaries were drawn as low detail polygons and derived from databases with 5-minute (10 km) resolutions. This information was based on data sets manufactured in the early 1980's and contained numerous inaccuracies. Low resolution data also produced

unrealistic littoral representations. While possessing the ability to overlay multiple numerical products, JMV did not contain any background topography or bathymetry information for display with numeric fields.

The addition of high-resolution background imagery imposes the need for a minimum of 128 MB of RAM and 1 GB of additional free disk space on machines currently running the software to maintain optimal performance. The current baseline MIDDS hardware installed at all Navy METOC ashore units exceeds these minimum requirements in all areas and JMV runs exceptionally well on the Metoc Integrated Data Display System (MIDDS) suite of workstations.

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III. BACKGROUND IMAGERY DISPLAY AND RENDERING

A. IMAGE DISPLAY AND PROCESSING FUNDAMENTALS

There are a number of tasks common to any software system designed to process imagery. Figure 2 is a schematic of a generic image display and processing system for environmental data. It complies with the general purpose image processing standards established by Green in 1983.

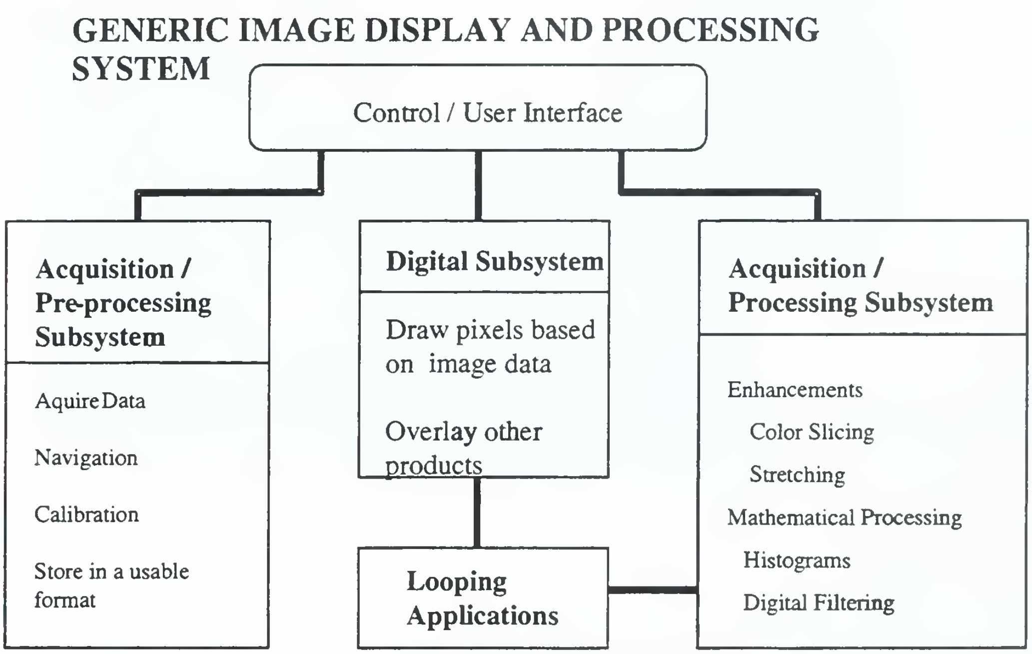

Figure 2. Components of a generic image display and processing system
From: Green, 1983

All systems have control software which provides the user-interface to the main functions of image display and processing, as well as other system level processes. The operating system of the computer may perform most of the control function, supplemented by a consistent user-interface (e.g. menu program) (Green 1983).

The image data must be ingested into the system, and this is the function of the Acquisition/Preprocessing subsystem. Once the data arrives in the computer it may need to be navigated, or geo-positioned to further facilitate overlay. Geo-locating imagery prior to ingest greatly simplifies this function. Finally the imagery must be written to a storage medium in a data format to be used by other software and hardware systems (Conlee, 1991).

The Applications subsystem consists of processing the imagery to enhance user understanding and retention of the data. The simplest category is image enhancement, where the pixel brightness is mapped to the display intensity in a fashion other than straight gray scale. This may consist of adjusting pixel brightness or filtering out certain colors to improve clarity. Stretching may also be applied to imagery. This is useful in highlighting a range of pixel values with greater intensity resolution. Processing may also take on more complex forms, such as digital filtering, edge detection, blending schemes, or a host of other more specialized information extraction applications (Conlee, 1991).

The Display subsystem must be able to take the image data, adjust it accordingly, and write final pixel values to memory serving as refresh for the video display. In addition this module includes sub-routines to overlay other environmental data such as contours and wind barbs. A system of environmental drawing tools for user annotation and the ability to overlay unit tracks is also useful. This requires the use of a pointing device which is also necessary for many other applications.

Another essential capability of environmental display systems is the ability to animate imagery that is obtained over time, in sequence. As seen clearly in the comparison made in Figure 3, integration of multiple data types, and animations in time

and spatial dimensions brings a level of realism to the data which greatly facilitates interpretation and analysis.

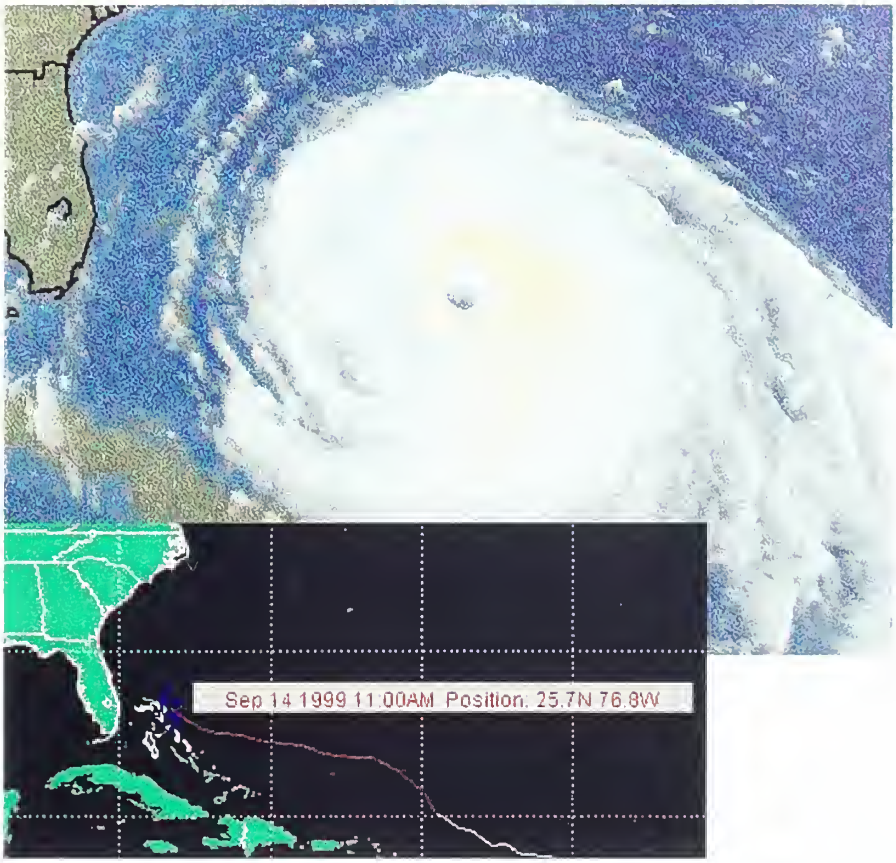

Figure 3. 3-D vs. 2-D views of Hurricane Floyd September 1999.
From: Storm Track System and Earth Watch, 2000.

B. 3-D AND 2-D RENDERING FUNDAMENTALS AND TECHNIQUES

Since the advent of the first numerical integrators in the 1950's and subsequent generations of super and micro computers, scientists and computer engineers have struggled with the task of converting computer generated results into formats which accurately convey information and present it in a familiar and understandable form.

In the arena of science the various specialties have differing requirements. The mathematician desires to show a parabolic function or render a fractal shape as shown in

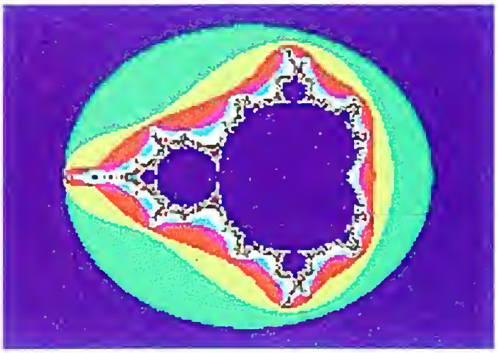

Figure 4. An Example of a Mandelbrot Fractal

Figure 4. The cardiologist wishes to probe the heart without cutting open a chest. The meteorologist attempts to show what the weather has been or will become. In meteorology however, any person who ever stepped outside his door has seen the sky on a sunny day or during a rain shower and understands what things are supposed to look like during differing types of weather. Unlike with heart surgeons and mathematicians, everyone has first hand experience with the weather. Representing weather systems in formats which end users are familiar has become a new science in and of itself.

When once the next generation of computer was anxiously awaited so a model could run with more data or parameters, now in tandem, graphic workstations and image processing systems continue to evolve allowing automated output to be rendered in more lifelike detail.

Some of the most important elements in visually relaying environmental data are the background over which they are presented and the palettes in which they are drawn. Realistic backgrounds, accurately portraying the topography and bathymetry, have been consistently sacrificed or relegated to case studies or other historical presentations where

real time processing is not involved. The costs in computer power and the complexity of the processes to utilize this data has historically been prohibitive in its use.

Rendering terrain for real time applications represents numerous challenges, but is worth the effort. Dr. Milton Halem, the Chief of Nasa's Earth and Space Data Computing center stated, "Our planet is best studied in a truly three dimensional medium made possible by our supercomputers, high speed networks, scientific visualization techniques, and information management tools." The major factors which must be considered for integrating digital terrain and environmental information are: (1) the differences in elevations around the globe, (2) the three dimensional (3D) parameters of the atmosphere, (3) the perspective of the viewer (4) the orientation of the light source, (5) the scale of the display from the microphysical (micrometers) to the planetary (thousands of kilometers), and (6) cluttering the display and hiding the environmental data with ambiguities.

For most of the eighties and into the nineties, virtual reality and real-time graphics applications have been implemented on platforms specifically developed for the task. Silicon Graphics has been the primary computer platform for real-time graphics systems because they have designed hardware specific to the needs to 3D rendering. The price of the technology required to do this kind of work has been decreasing over the last few years, and in many situations the ability to use high speed computer graphics has moved to the personal computer.

Currently, most 3D imagery is stored into some type of world file. These worlds have defined boundaries like standard digital images, but contain additional dimensional information displaying depth or height. Most virtual display worlds are small with

medium to low detail models. Part of this is due to the constraints on the systems. Only specific numbers of polygons can be rendered per second and exceeding this number will slow the computer down too much for practical use. High-detailed displays of model and satellite data take considerable resources to produce.

Currently, it remains difficult for computers to store and display high detail displays the size of the Earth. Because of this, certain concessions must be made. In computer science, the choice that must often be made is between space and speed. The more memory a process can use, the faster the processing. The challenge for computer scientists is finding ways to use less memory without sacrificing too much speed. In general, speed is not something that can be sacrificed, because these real-time applications must be fast enough to cause no visible slowing in the rendering.

Two different techniques have been developed over the past years for the visualization of volumetric data, allowing for extracting different kinds of information from the 3-D data sets. The first technique is known as contouring (Lorensen, 1987), where all values in the data set that are below a specified threshold are identified. This results in a discrete, iso-valued surface called contour. This surface can be rendered into a three dimensional perspective by using shading techniques. The intensity (color or gray-scale) at each pixel, corresponding to a polygon, is calculated by attributing one color per facet, by scalar interpolation (Gouraud shading) or vectorial interpolation (Phong shading) (Savary, 1999).

Using the constant shading technique, each facet of the object is illuminated by an average value for the entire polygon. This approach is fast and very simple, but it

givesquite poor realistic results and non smooth surfaces. This is enhanced by the Mach effect: the intensity at the vicinities of the edges is overestimated for light values and underestimated for dark values (Savary, 1999).

The Gouraud shading technique eliminates intensity discontinuities by interpolating the intensity for each polygon. It uses the normal vector at each vertex and edges of the polygon mesh (obtained by averaging each normal of the facets sharing the same edge).

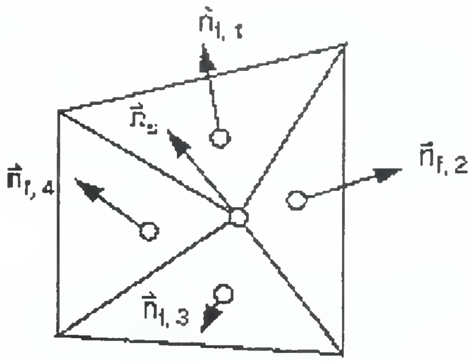

Figure 5. Gouraud Shading

As seen in Figure 5, the model determines the intensity at each vertex and then interpolates linearly between each normal along the edge and then the same way between the edges for every scan-line. This scan-line algorithm is very often hardware implemented. The Mach effect is almost completely eliminated (except for very high curved surfaces).

Figure 6 shows Phong shading which is similar to Gouraud shading based on an interpolation algorithm except that this time, the interpolation is made by vectors. It uses the normals at each facet, the average normals at each vertex, and interpolates vectorially along the edges between the vertex, and then interpolates the same way between the

edges along the scan-line (very extensive calculation, as it has a normalization calculation at every step).

The most common problems encountered with interpolated shading are overcome by utilizing triangles as polygons or by enhancing the numbers of polygons (which is expensive). For example, a highly curved surface (typically a sphere) will clearly have a

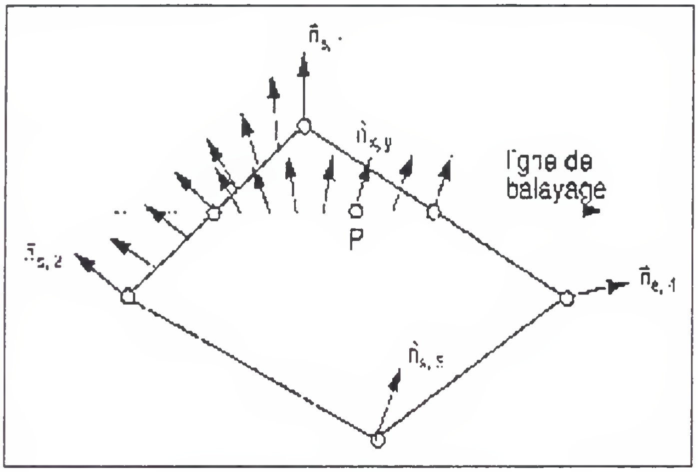

Figure 6. Phong Shading

polygonal silhouette. This situation can be improved by breaking the surface into a greater number of smaller polygons, but will be more expensive.

The second technique, known as volume rendering (Drebin, 1988), treats the entire data set as a contiguous density cloud and is visualized by modulating the opacity of the object based on the values present in the data set (Savary, 1999).

After testing and comparing the output from a variety of software packages, programs using vector interpolation seem to produce the best rendering of specular lights and was the method utilized for the JMV Image Database. This technique was selected primarily because it was incorporated into the GIS software used for terrain rendering

which produced the desired imagery. Of equal import this computational method ran fast enough to render images of the entire globe.

C. DATA SOURCES

Internationally, there are literally countless sources of reputable data sets containing environmental background imagery. As with traditional paper maps and charts, each has unique value and disadvantages.

The following list names online locations where global data can be reliably obtained via the world wide web. These sites are monitored 24 hours a day 7 days a week and contain GIS data distributed by the United States Government. Most GIS information may be also ordered on magnetic media or by CDROM distribution.

- United States Geological Service EROS Data Center [http://edcdaac.usgs.gov/gtopo30/gtopo30.html]
- Naval Oceanographic Office [http://www.navo.navy.mil/navdriver.html]
- National Imagery and Mapping Agency [http://164.214.2.59/geospatial/geospatial.html]

D. SCALES OF VISUALIZATION

There are a number of factors to consider when designing envirionmental visualizations. Temporal and spatial scales as represented in Figure 7 and the availibility of global data at these resolutions, coupled to the current and near future capabilities of individual workstations (memory, speed, storage) are all driving factors.

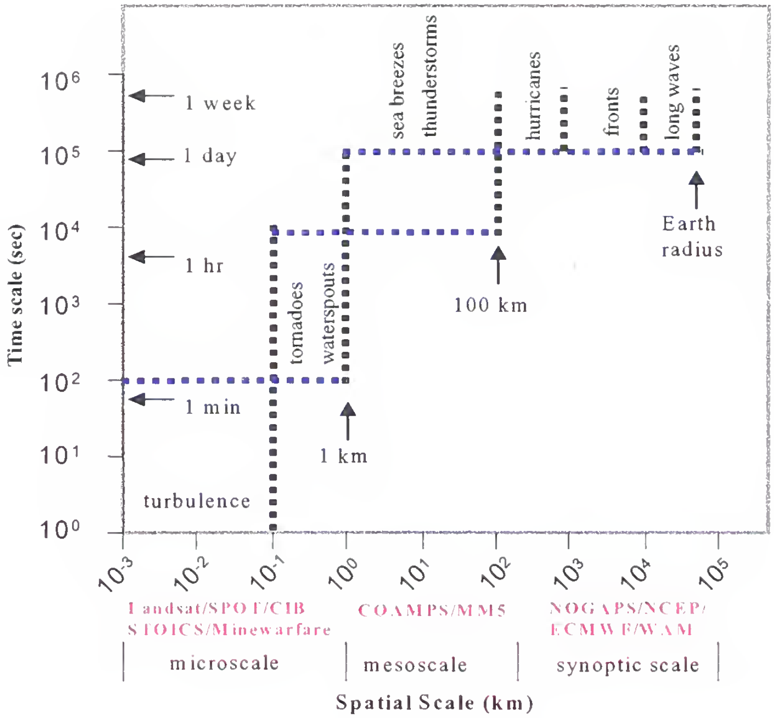

Figure 7. METOC Scales. From: Anthes et al, 1978

1. Synoptic Scale (Global/Regional)

In the context of traditional meteorological and oceanographic modeling, the preeminent scale of viewing information has been anchored to the resolution of the model grid; nominally 1 degree (81km).

2. Mesoscale

In the last 20 years weather satellites and as enhanced global observation grid have narrowed the 81 km grid down to about 1 km. Only in the last 2.5 years has Pentium based workstation power been available and cost effective enough to allow visualization tools the ability to match the available imagery.

In 1997 numerous regional and mesoscale models became operational at a variety of sites throughout the nation. Output grids of 27 km, 18 km, 9 km, and now 6 km and even 1 km have now become available for routine analysis and interpretation. This has further emphasized the need to improve the scales for visualization as forecasters attempt to resolve features interacting with realistic topography.

3. Sub-Mesoscale (Microscale)

The current trend of increased computer resources, smaller grid scales, and finer scale observing systems coupled with the instant availablity of these products will further push visualization scales. The completion of the Shuttle Radar Topography Mission and the resultant high resloution (10 or 5 m) digital elevation data will provide global topographic data bases which will facilitate global visualizations on this scale. Faster networks and increasingly powerful workstations will also drive the trend toward even more realistic 3-d visualizations as scinetists attempt to understand and relate small scale environmental perturbations. As demonstrated in the past, remote observing resources are still out pacing increases in model resolution. The challenge of maximizing these tools in combination with relatively coarser scale modeling is an issue which needs consideration.

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IV. JOINT METOC VIEWER GLOBAL GIS DATABASE (JMV GIS-DB)

Data was required to be available in a format that could be converted if necessary, for integration into JMV. Further constraints required that the final interface must not produce noticeable system slowing or lock ups when looping imagery, and that all data sources must be updated responsively by a third party; (1) National Imagery and Mapping Agency (NIMA), (2) Naval Oceanographic Office (NAVO), (3) United States Geological Survey (USGS), or a (4) commercial vendor.

A. DATA SOURCE CHARACTERISTICS

Tables 2 – 11 list all global data sources considered for the JMV interface. Resources highlighted in blue were actually used in project. In the case of bathymetry, DBDB-V was employed but it was obtained via NIMA as part of the World Vector Shoreline Package.

Table 2. GTOPO 30 Specifications

A. GTOPO30	
(1) Statistics:	
Spacing:	**30 arc seconds ~ 1 km**
Cost:	**Free, no use or redistribution charges.**
Coverage:	**100% Global**
Maintenance:	**USGS, upgrades are currently planned**
Data Sources:	**DTED (NIMA Digital Terrain Elevation Model), DCW (Digital Chart of the World), Antarctic, Australian, Japanese, and New Zealand National Databases**
Datum:	**World Geodetic System (WGS) 1984**
Units/Reference Level:	**Meters, referenced to mean sea level**
Accuracy:	**RMSE 70m overall vertical accuracy RMSE 3 m vertical accuracy at sea level**

Table 3. World Vector Shoreline Specifications

B. World Vector Shoreline 1999	
(1) Statistics:	
Spacing:	1km/100m
Cost:	Free, no use or redistribution charges for DOD users.
Coverage:	100% Global Shorelines
Maintenance:	NIMA
Data Sources:	Cartographic and Satellite Imagery Data (Scale 1:250,000)
Datum:	WGS-84 and Mean High Water Mark
Units/Reference Level:	Meters
Accuracy:	Horizontal Accuracy from 1990 specifications is 500m (1999 specs not currently available.)

Table 4. Clear Satellite Coverage Specifications.

C. USGS/NASA global clear coverage satellite imagery.	
(1) Statistics:	
Spacing:	1 km
Cost:	Free, no redistribution fees
Coverage:	100% Global
Maintenance:	USGS Earth Resources Observing Data Center (EROS)
Data Sources:	Advanced High Resolution Radiometer (AVHRR) from NOAA Television Infrared Observation Satellite (TIROS)
Datum:	5 Channel, raw AVHRR aligned with Digital Chart of the World for inland waters and WVS for coastlines.
Units/Reference Level:	Goode's Interrupted Homolosine Projection
Accuracy:	1km, 10 bits

Table 5. DTED Level 0 Specifications.

D. DTED Level 0	
(1) Statistics:	
Spacing:	30 arc seconds ~ 1km
Cost:	Free, no use or redistribution charges.
Coverage:	~90% Global
Maintenance:	NIMA, ongoing, 1999 latest release.
Data Sources:	DTED Level 1 (NIMA Digital Terrain Elevation Model), 9 other national cartographic resources.
Datum:	World Geodetic System (WGS) 1984
Units/Reference Level:	Meters, referenced to mean sea level
Accuracy:	Currently unknown

Table 6. DTED Level 1 Specifications.

E. DTED Level 1	
(1) Statistics:	
Spacing:	3 arc seconds ~ 100 m
Cost:	Free, no use or redistribution charges for DOD.
Coverage:	100% Global
Maintenance:	NIMA, ongoing, 1999 latest release.
Data Sources:	DTED (NIMA Digital Terrain Elevation Model), Classified.
Datum:	World Geodetic System (WGS) 1984
Units/Reference Level:	Meters, referenced to mean sea level.
Accuracy:	~20 meter vertical accuracy for a 1 degree cell.

Table 7. ETOPO5 Specifications.

F. ETOPO5 (National Geophysical Data Center, 1988)	
(1) Statistics:	Ocean Depth and Land Mass Elevation Data Set
Spacing:	5 arc minutes ~ 10 km
Cost:	Free, no use or redistribution charges.
Coverage:	100% Global
Maintenance:	NOAA/NESDIS/NGDC
Data Sources:	Bathymetry: NAVO 1987 / Topography: Various National cartographic sources/FNMOC 10 minute gridded model heights
Datum:	WGS-1984
Units/Reference Level:	Meters
Accuracy:	Uncertain due to sources of data, see reference document for a more detailed discussion (Reference Document)

Table 8. NDVI Specifications.

G. NDVI (Global Vegetative indices)	
(1) Statistics:	
Spacing:	1 km
Cost:	Free, no redistribution costs
Coverage:	100% Global 10 day composites
Maintenance:	USGS Earth Resources Observing Data Center (EROS)
Data Sources:	Advanced High Resolution Radiometer (AVHRR) from NOAA Television Infrared Observation Satellite (TIROS)
Datum:	2 Channel, 8 bit, raw AVHRR aligned with Digital Chart of the World for inland waters and WVS for coastlines.
Units/Reference Level:	((NIR-VIS)/(NIR+VIS)) NIR:AVHRR Channel 1, VIS:AVHRR Channel 2
Accuracy:	1 km, 8 bits

Table 9. DBDB-V Specifications.

H. DBDB-V	
(1) Statistics:	
Spacing:	Variable: 5 arc minutes – .5 arc minute
Cost:	Free, no redistribution costs
Coverage:	100% Global
Maintenance:	Naval Oceanographic Office
Data Sources:	Fleet of Navy Hydrographic Vessels, Historical Databases
Datum:	Horizontal: World Geodetic System (WGS) 1984, Vertical: Mean Sea Level (MSL)
Units/Reference Level:	Meters
Accuracy:	Variable: 5 arc minutes – .5 arc minute

Table 10. Digital Chart of the World Specifications.

I. Digital Chart of the World	
(1) Statistics:	
Spacing:	1:1,00,000 over land, 1 arc minute - 5 arc minute bathymetry
Cost:	Free, no redistribution costs
Coverage:	100% Global
Maintenance:	No upgrades planned. unknown.
Data Sources:	U.S. Defense Mapping Agency Operational Navigation Chart (ONC) series and the Jet Navigation Charts (JNCs) for the region of Antarctica, Advanced Very High Resolution Radiometer (AVHRR) for CONUS Vegetation, DBDB-V for bathymetry
Datum:	Horizontal: World Geodetic System (WGS) 1984, Vertical: Mean Sea Level (MSL)
Units/Reference Level:	Meters
Accuracy:	Variable

Table 11. NOAA's Globe Database Specifications.

J. NOAA's Global Land One-kilometer Base Elevation	
(1) Statistics:	
Spacing:	30 arc seconds ~ 1 km
Cost:	Free, no redistribution costs
Coverage:	100% Global
Maintenance:	National Geodetic Data Center
Data Sources:	GLOBE borrowed procedures, and in some cases data, from previous global DEM efforts. DTED (NIMA Digital Terrain Elevation Model), DCW (Digital Chart of the World), Antarctic, Australian, Japanese, and New Zealand National Databases. USGS used some of its 3" data in its GTOPO30 compilation that contributed significantly to GLOBE Version 1.0. National maps of Brazil, Peru, and Asian nations.
Datum:	Horizontal: World Geodetic System (WGS) 1984. The

	vertical units represent elevation in meters above Mean Sea Level.
Units/Reference Level:	Meters
Accuracy:	Variable

Table 11 (Continued)

B. PROJECTION CONSIDERATIONS

Imagery, lines, contours, and polygons produced for this upgrade were required to conform to a variety of projections. JMV and METCAST utilize different projections for different map areas.

1. Mercator Projection

Satellite areas and principal product areas are drawn using Mercator projection. Most of the charts used for marine navigation, and a good many of those used for air navigation, are based on the Mercator projection (Maloney, 1978). This is the main reason the bulk of the work done with JMV utilizes this projection. Its principle advantage still lies in the use of a purely rectangular graticule for latitude and longitude.

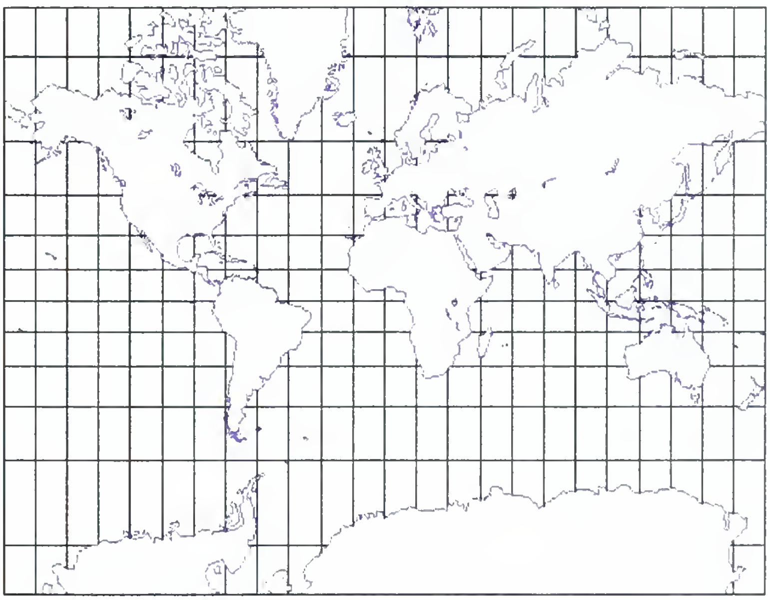


Figure 8. Mercator Projection.
Source: Picture Gallery of Map Projections, Havlicek, 2000

Thus rhumb lines can be laid between any to points to produce accurate distance

measurements. Its principal disadvantage lies in the fact that with increasing latitude object size is progressively exaggerated. An example of this can be seen in Greenland and Antarctica on Figure 8. On the Mercator projection Greenland appears to be larger than South America when in reality it is 1/7th the size of the southern continent. (Maloney, 1978).

2. Unprojected or Geographic Projection

Figure 9 shows this projection that is currently utilized for retrieving products on a global scale. Unprojected maps include those that are formed by considering longitude

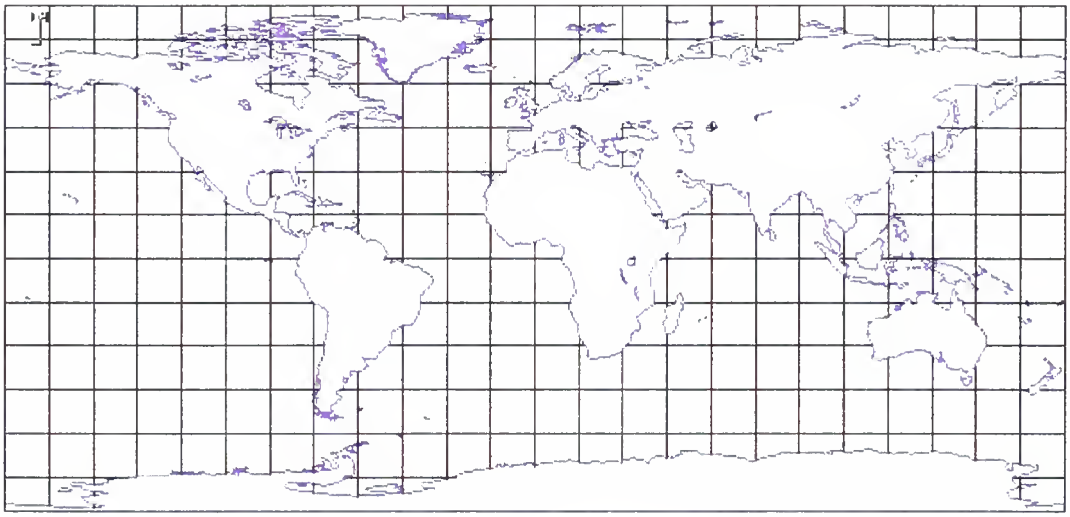


Figure 9. Geographic Projection.
From: Picture Gallery of Map Projections, Havlicek, 2000

and latitude as a simple rectangular coordinate system. Scale, distance, area, and shape are all distorted with the distortion increasing toward the poles (Dana, 1999).

3. Polar Stereographic

As seen in Figure 10, this projection is currently utilized for product retrieval into areas centered on the North or South Pole. Stereographic projections are used for

navigation in polar regions. Directions are true from the center point and scale increases away from the center point as does distortion in area and shape (Dana, 1999).

C. FORMAT CONSIDERATIONS

All JMV GIS-DB imagery utilizes the tagged image format (. tif/. tiff). This is

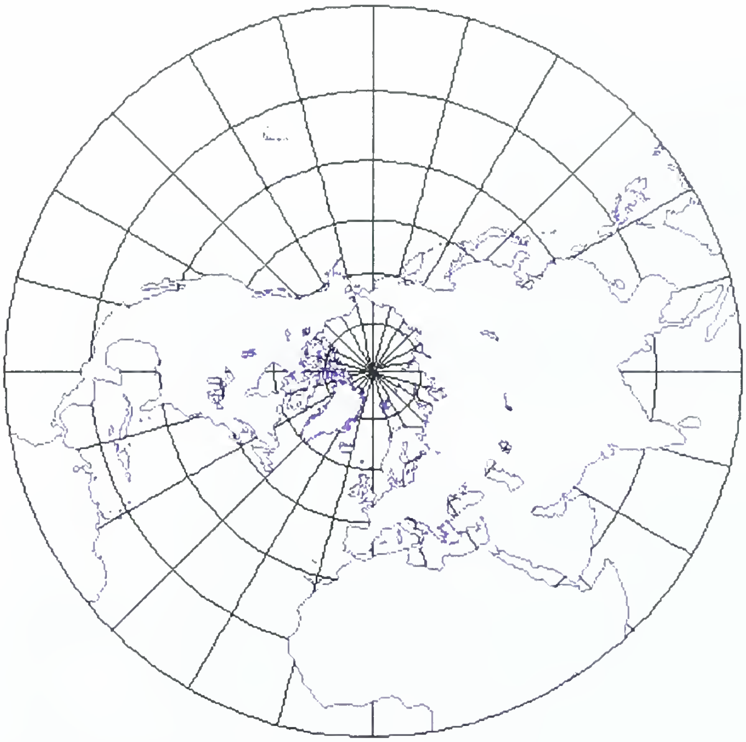


Figure 10. Polar Stereographic.
Source: Picture Gallery of Map Projections, Havlicek, 2000

one of the most popular and flexible of the current public domain raster file formats. TIFF is primarily designed for raster data interchange. Its main strengths are a highly flexible and platform-independent format that is supported by numerous image-processing applications. Another feature of TIFF, which is also useful, is the ability to decompose an image by tiles rather than scan lines. This permits much more efficient access to very large imagery which has been compressed (since one does not have to decompress an entire scan line). Theoretically, TIFF can support imagery with multiple

bands (up to 64K bands), arbitrary # bits per pixel, data cubes, and multiple images per file, including thumbnail sub sampled images.

TIFF images may utilize numerous compression schemes for storage and transport. JMV GIS-DB recognizes: (1) raw uncompressed, (2) pack bits, (3) and Lempel-Ziv-Welch (LZW) schemes. JMV GIS-DB uses only 1-64 bit integer, signed or unsigned pixel formats. TIFF images allow programmers to insert customized data such as geo-referencing information and file sub-type. This information is stored as bytes known as tags. The versatility of tags is derived from the fact they can contain, or point to, data that is any number of bytes in size and is located anywhere within a TIFF image file directory (IFD) section (Murray, 1994). This "tagged" information can be read by other programs and used by them for file processing and placement.

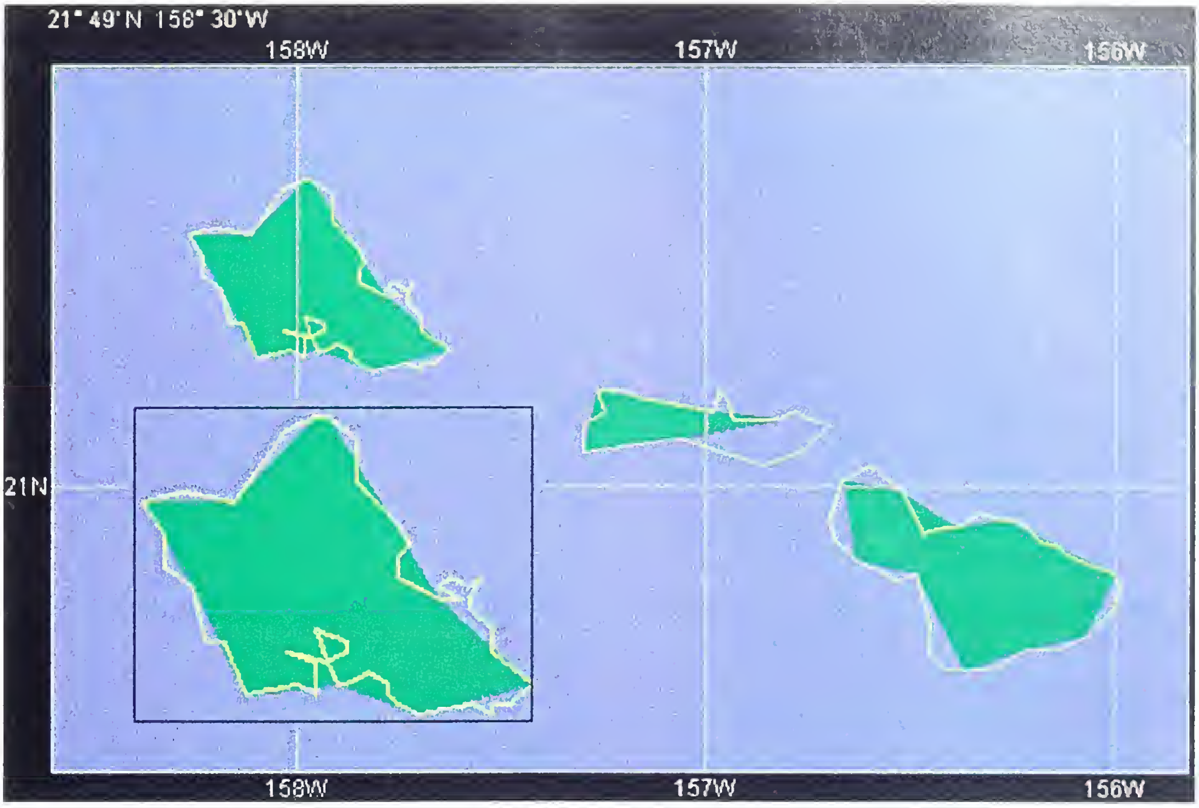
D. STORAGE CONSIDERATIONS

JMV GIS-DB requires 1 gigabyte of disk storage for optimal performance. It will run using a fraction of this space but the image database must be resident on a CDROM and data areas may be limited in size. JMV GIS-DB data and imagery is available on the distribution CDROM or via the World Wide Web.

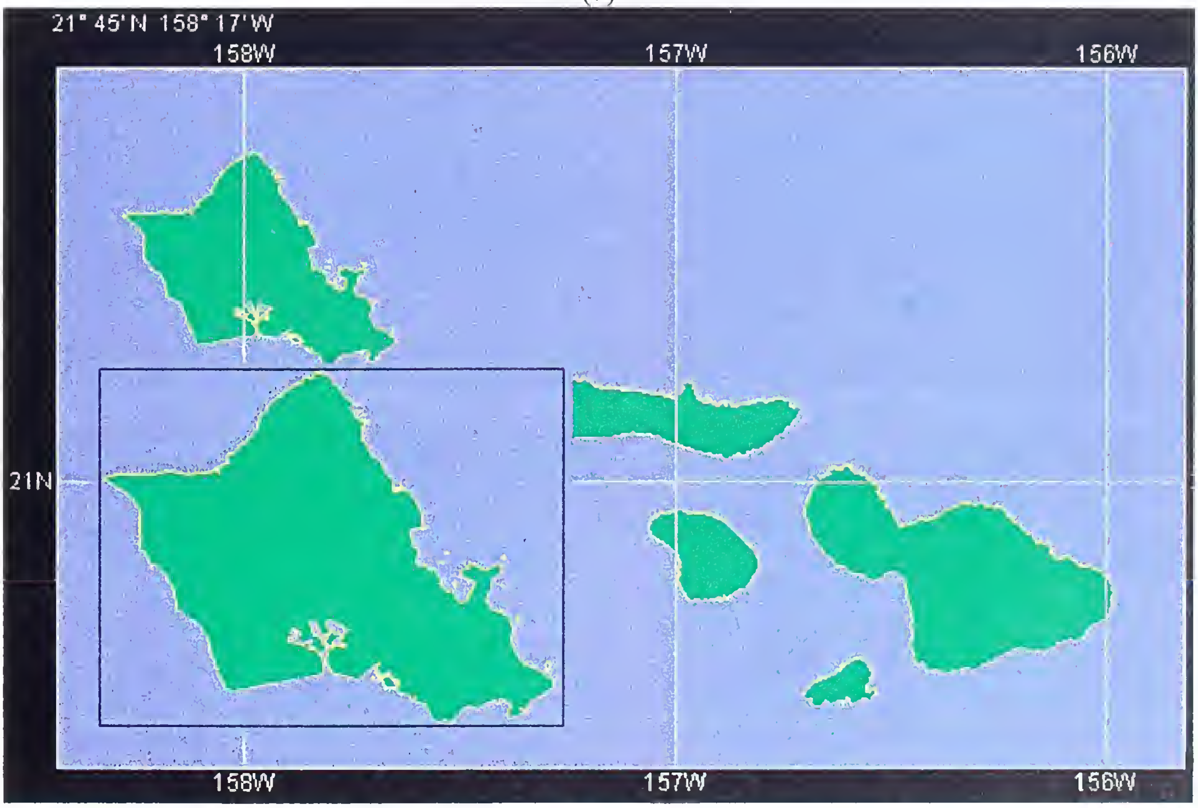
E. A VISUAL LOOK AT THE UPGRADES

1. Higher Resolution Coastlines

JMV 3.1 and below utilized coastlines derived from the Digital Chart of the World (1982). JMV GIS-DB utilizes coastline data derived from the World Vector Shoreline 1999 Database. Resolution of line drawn coastlines was improved from sampled 1 degree latitude to 100 m. Figure 11 illustrates this improvement.



(a)



(b)

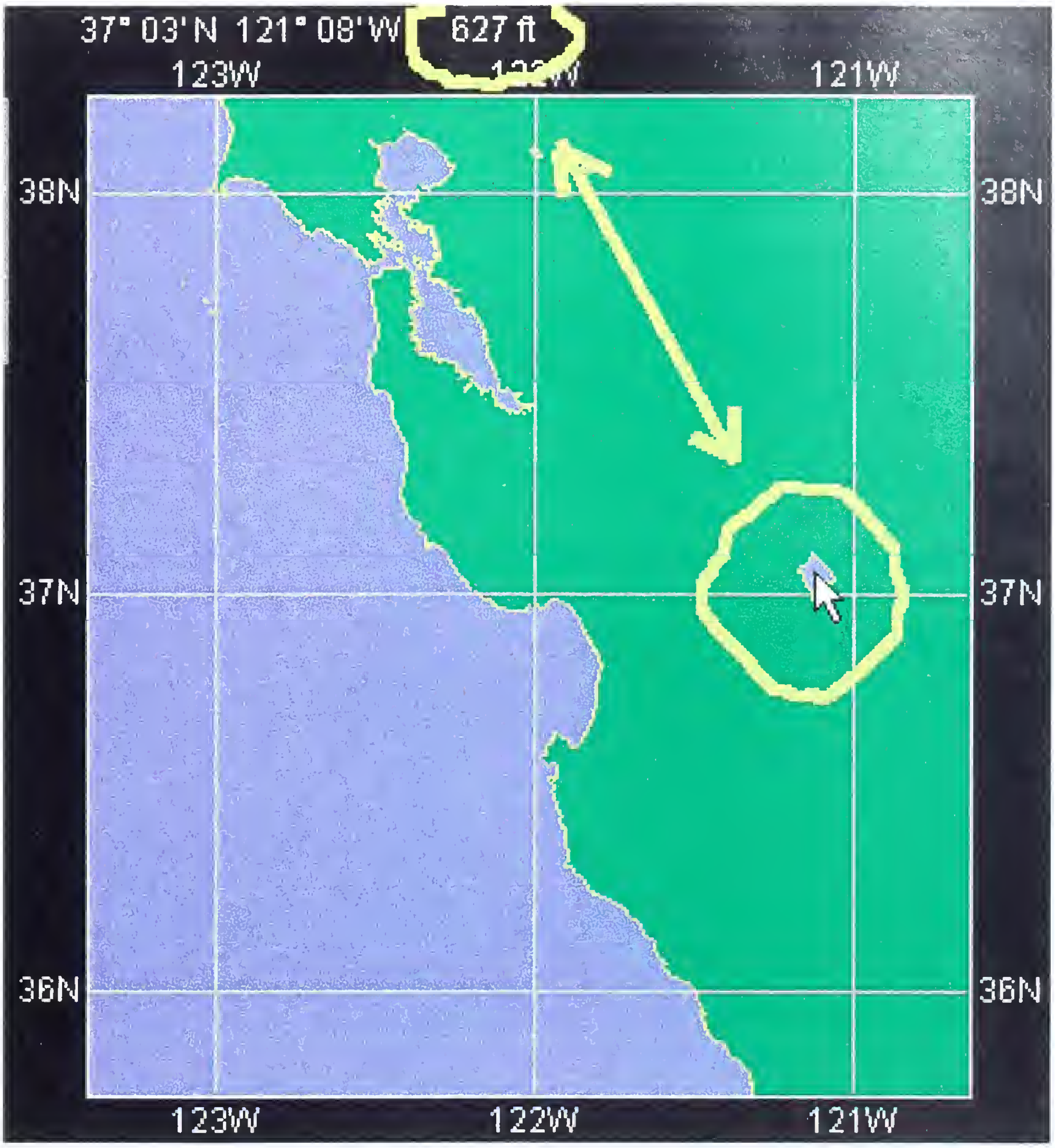
Figure 11. Coarse and High resolution coastlines. Image (a) shows older coarser resolution coastlines. Image (b) shows higher resolution coastlines. Note the appearance of the islands of Lanai and Kooalawe to the west of Maui.

2. Addition of a scrolling contourable global GIS-Database including bathymetry and topography

No terrain elevation or bathymetric information was available in JMV 3.1 and below. Terrain and bathymetry information is now mapped to every background area. Elevation information was derived from the DTED Level 1 terrain database. Depth information was derived from the DBDB-V database. Information is automatically displayed at the top of each map as the cursor changes position over the area as shown in Figure 12. Additionally this background database can be contoured or color filled as shown in Figures 13 and 14.

3. Updated geo-political boundaries

JMV 3.1 and below utilized CIA World Fact book 1982 database derived political boundaries. JMV 3.2 and above uses political boundaries derived from World Vector Shoreline 1999 data and has undergone further modifications to reflect recent changes in Bosnia. Figure 15 illustrates political boundary upgrades.



(a)

Figure 12. Elevation readout. Image (a) shows the mouse hovering over California's San Luis Reservoir and the corresponding elevation readout displaying 627 ft above mean sea level at the top of the screen.

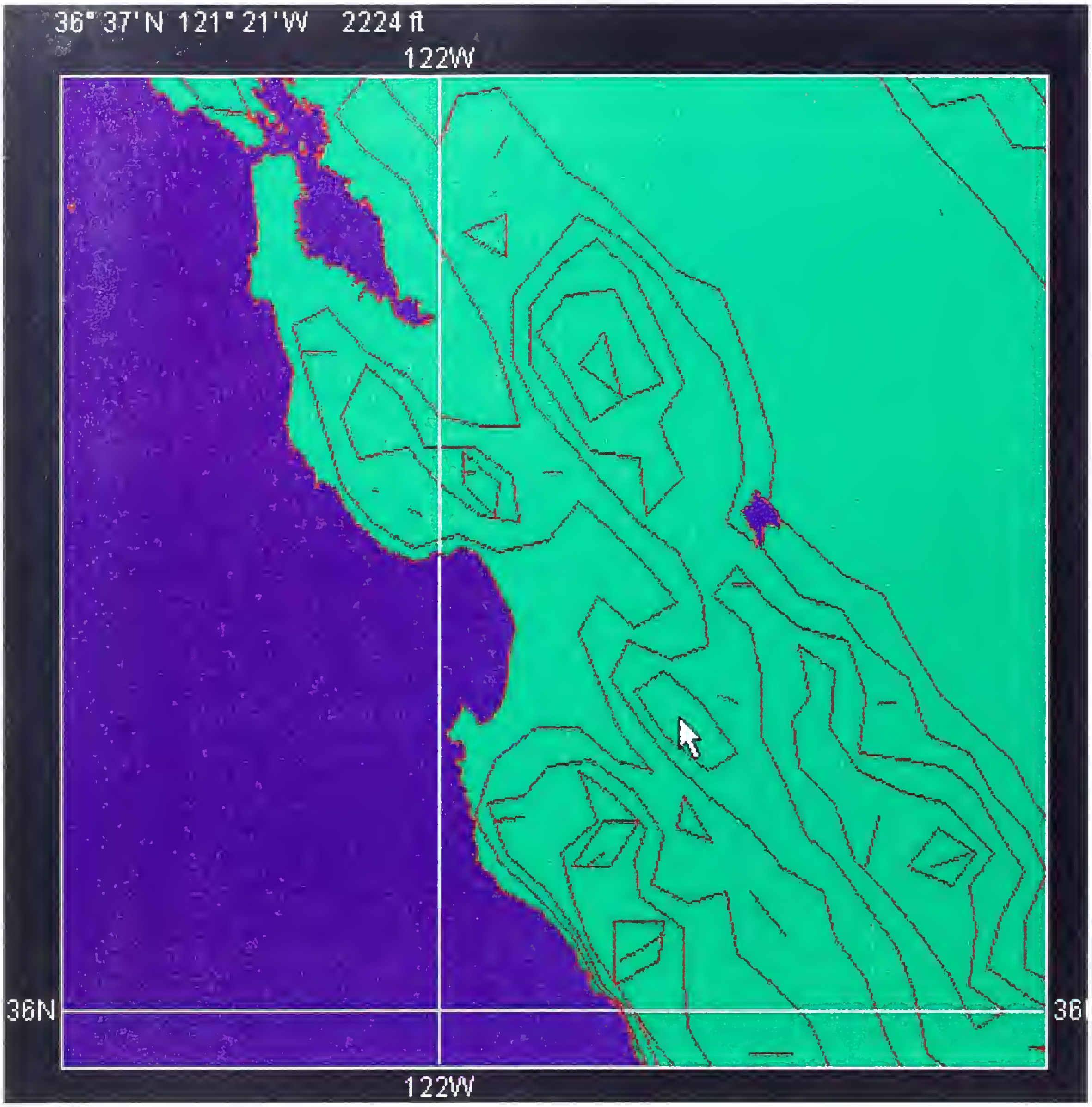
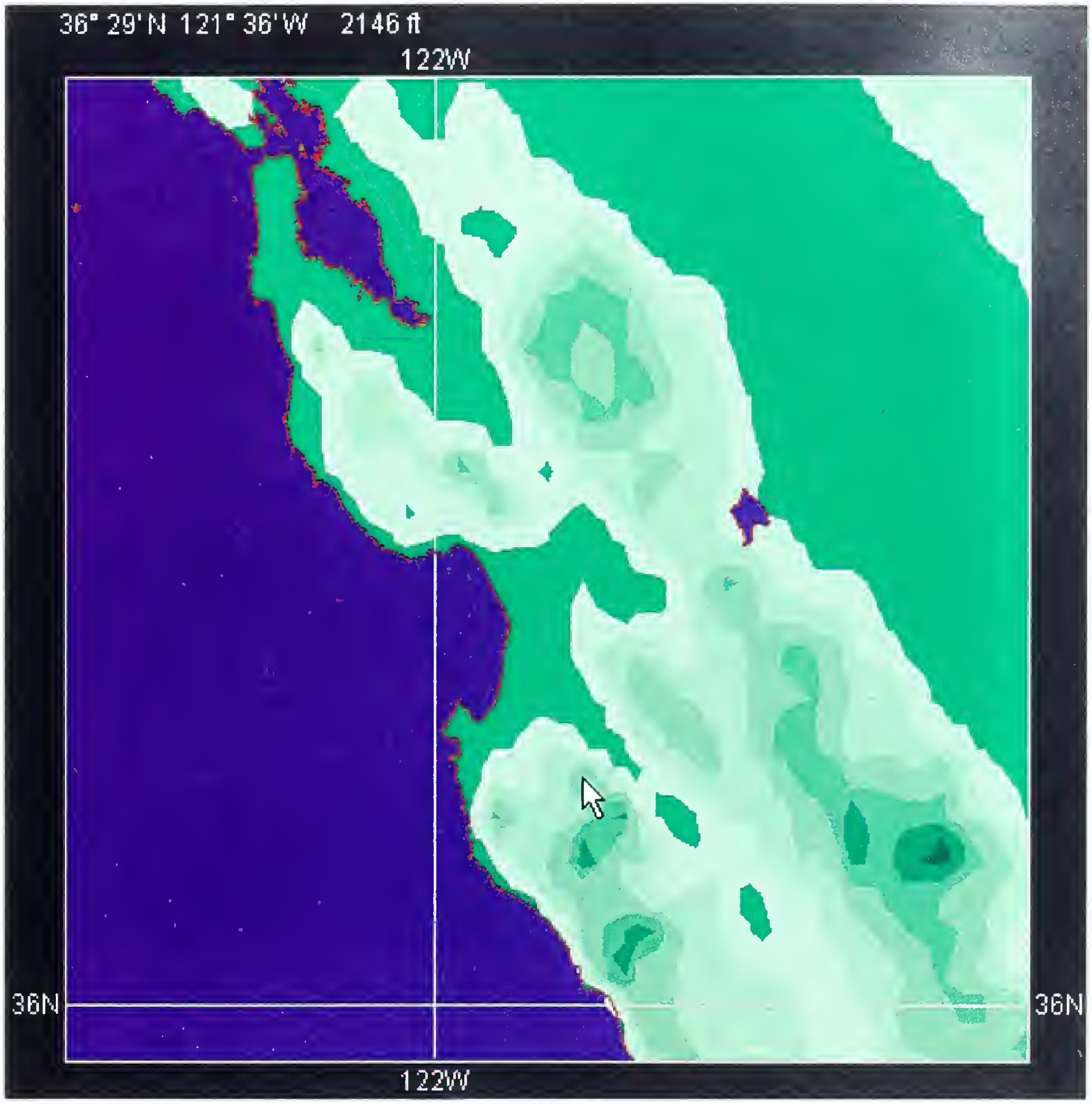


Figure 13. Topographic contours and elevation display. The mouse is hovering over a peak in California's Gabilan Range with the elevation readout displaying 2224 ft above mean sea level at the top of the screen. Topographic Contours spaced at user defined intervals are also displayed.



(a)

Figure 14. Topographic shading and elevation display. The mouse is hovering over California's Mount Toro with the elevation readout displaying 2146 ft above mean sea level at the top of the screen. Topographic Color filling has been applied at user specified intervals and colors.

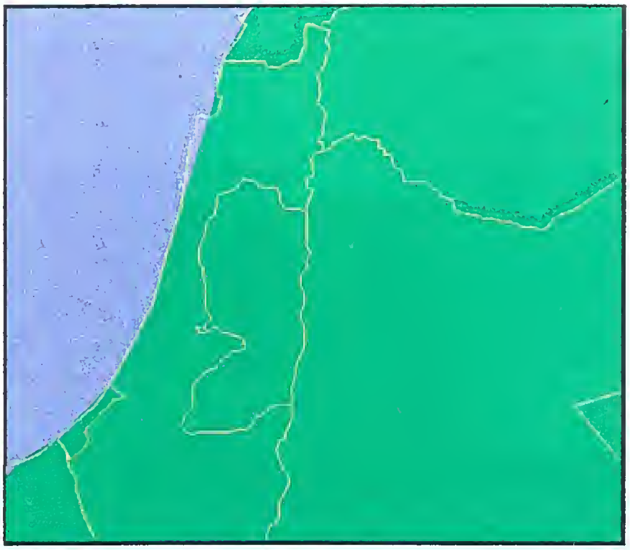
(a)

(b)

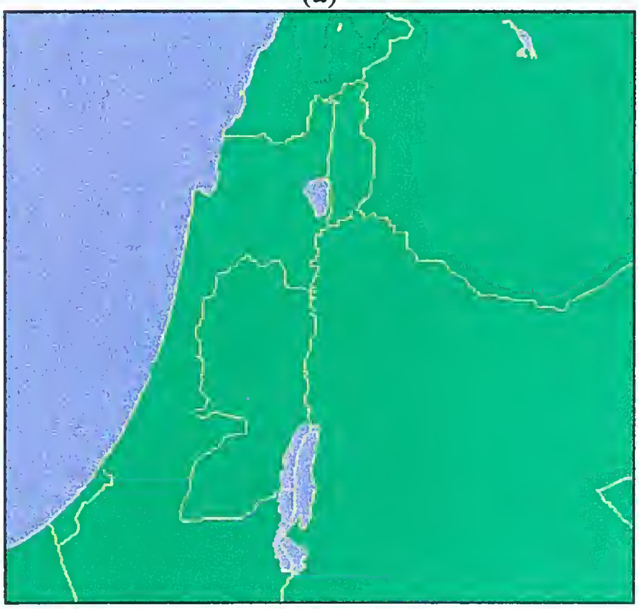
Figure 15. Political Boundaries. Image (a) using older border information includes boundaries for the Kosovo autonomous region. Image (b) shows the revised borders of Serbia and the addition of new towns like Otok Rab in Croatia

4. Upgraded hydrographic information (rivers and lakes)

JMV 3.1 and below utilized the Digital Chart of the World database derived hydrography (rivers and lakes). JMV 3.2 uses hydrography derived from World Vector Shoreline 1999 data. Figure 16 illustrates the addition of small scale hydrologic features.



(a)



(b)

Figure 16. Inland waters. Image (a) shows absence of Lake Tiberias (Sea of Galilee) and The Dead Sea in old version. Image (b) shows the inclusion of these features. Note also the border around the Israeli held Golan Heights in the North in the new version.

5. Addition of a 3-D rendered global image database and the required interface and layering technology to make it work

JMV 3.1 and below had no capability to display anything other than resident 2D polygon backgrounds. JMV 3.2 and above now has the capability to import and geo-locate any image obtained by the local user as a background for co-displaying with FNMOC distributed environmental data. Figure 17 underscores JMV's new capabilities and illustrates new menu items.

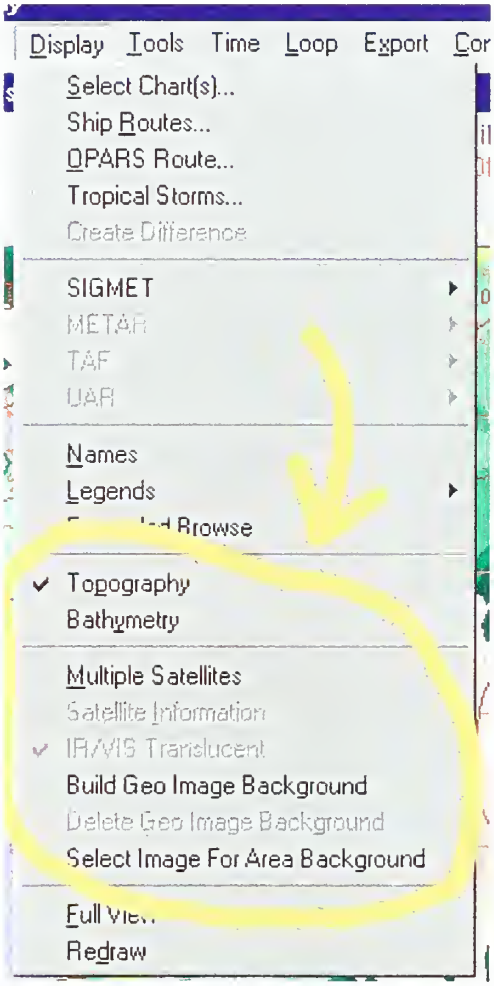


Figure 17. New Geo-control interface.

JMV 3.2 now includes has the additional capabilities of building studio and presentation quality 1 km resolution rendered backgrounds from the GIS-DB. Figures 18 – 22 provide a visual evolution of these capabilities and illustrate the visual characteristics of terrain imagery produced with the new interface. These backgrounds are color coded with natural tones to both accurately convey elevation information and to remain visually appealing.

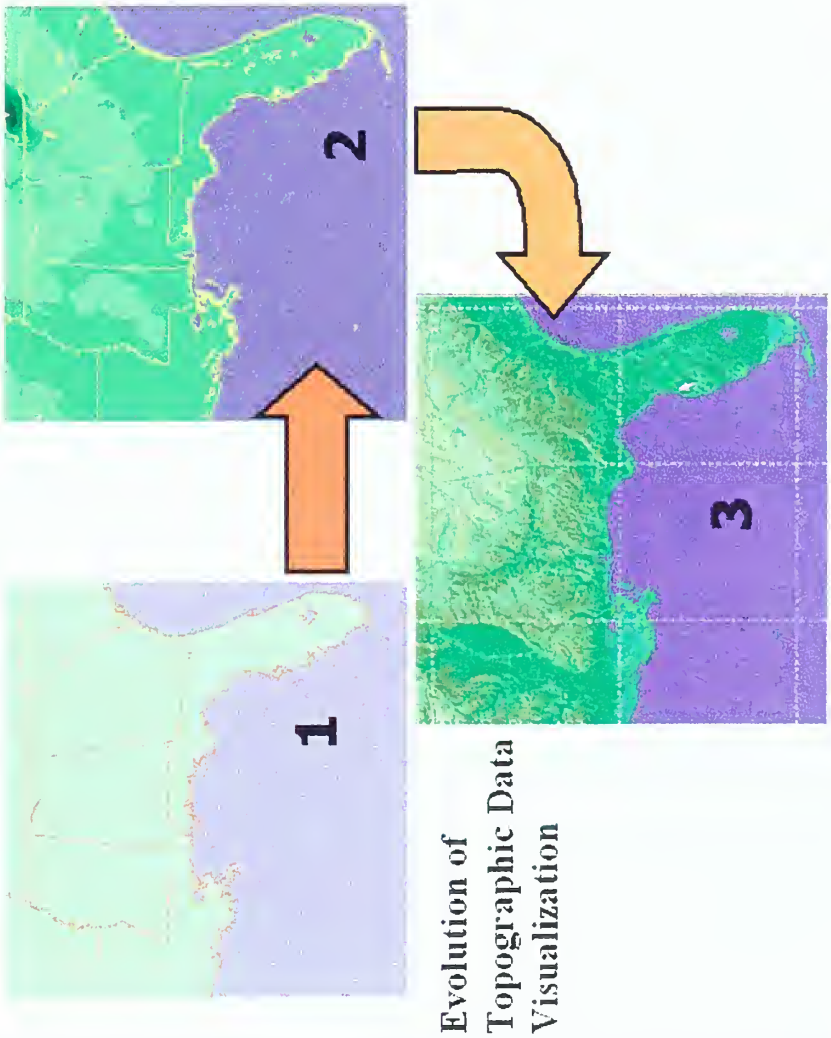
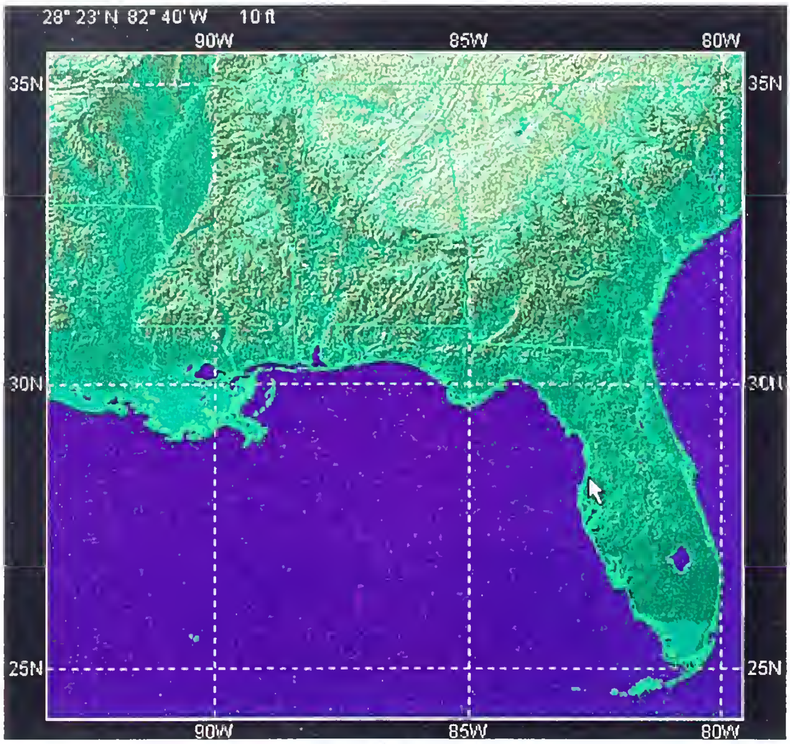
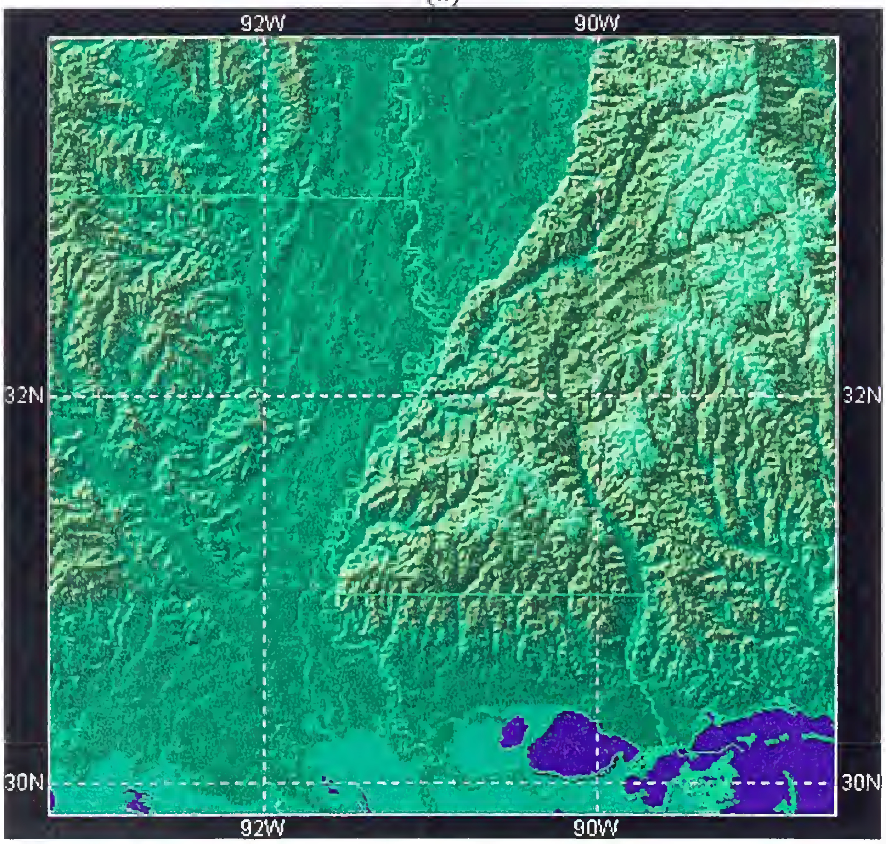


Figure 18. Major steps in the evolution process from coarse coastlines and no topography to an embedded high-resolution data set.



(a)



(b)

Figure 19. Topographic renedering. Image (a) shows rendered topography of the Southeastern United States. Notice the mouse located over Homosassa Springs, FL, and the corresponding readout of 10ft above mean sea level. Image (b) shows a zoomed in section from image (a) of the Mississippi river valley.

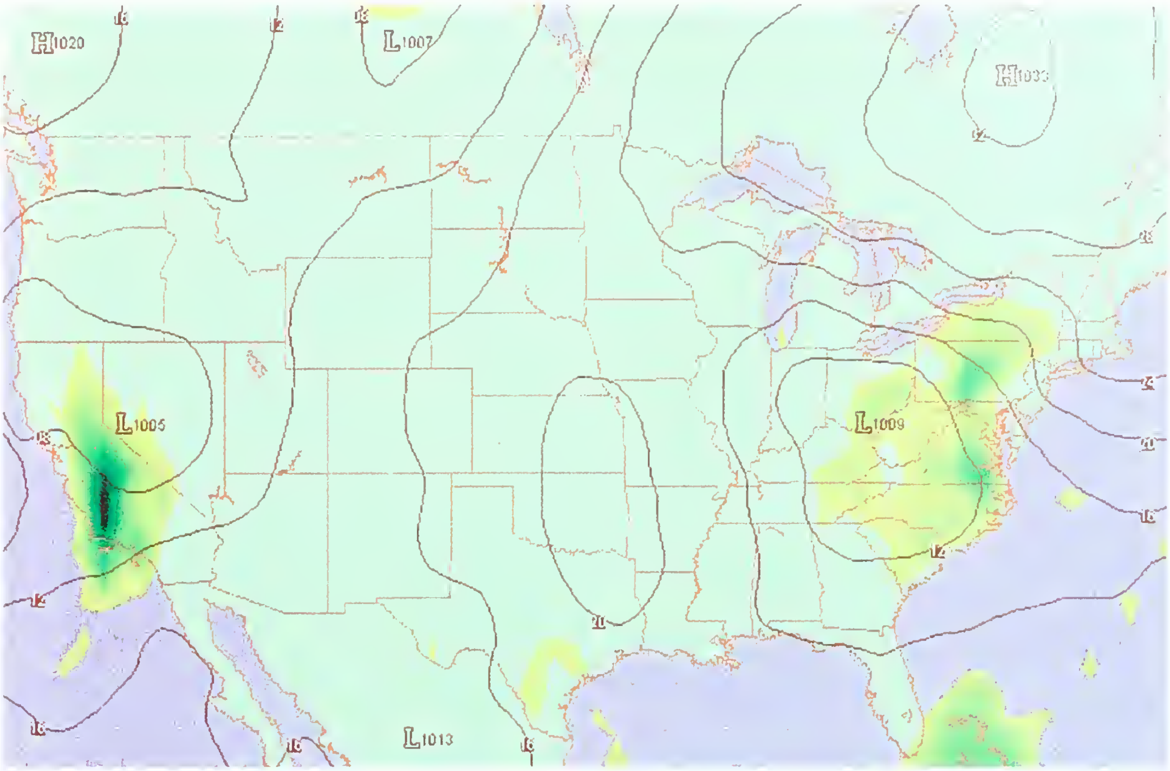


Figure 20. JMV 3.1 with no terrain and high resolution coastlines installed. NOGAPS Surface Pressure and 12 Hour precipitation forecasts co-displayed on a synoptic scale.

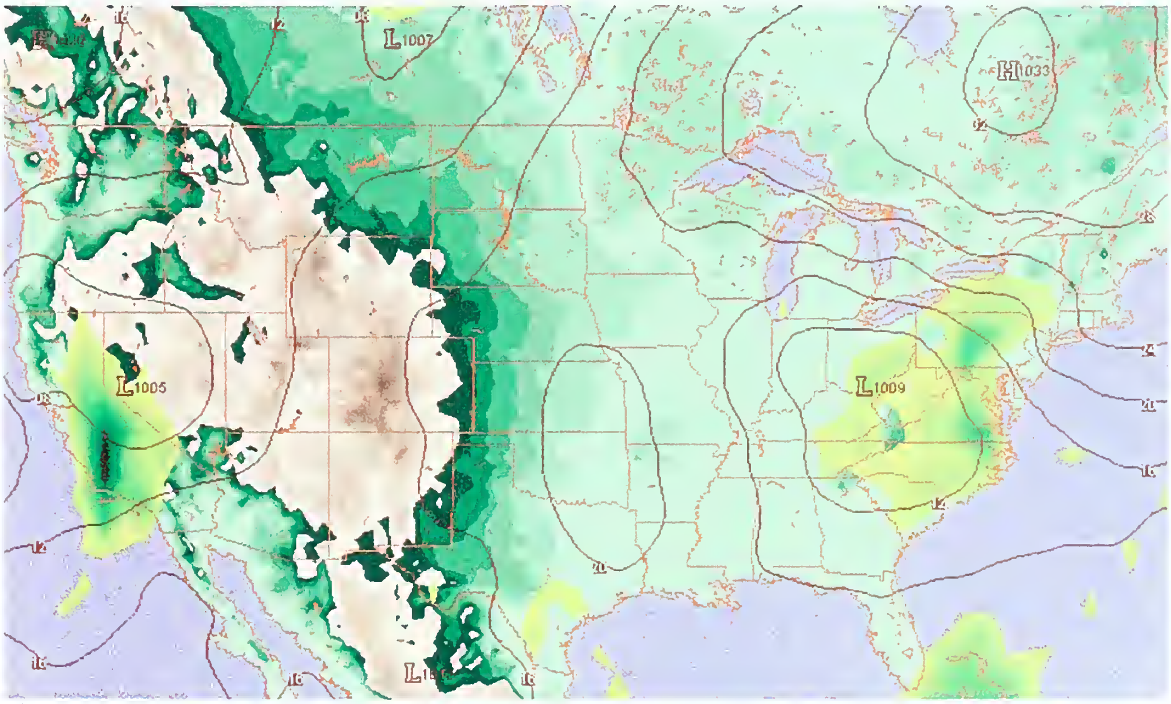


Figure 21. JMV 3.2 with color filled terrain and high resolution coastlines installed. NOGAPS Surface Pressure and 12 Hour precipitation forecasts co-displayed on a synoptic scale.

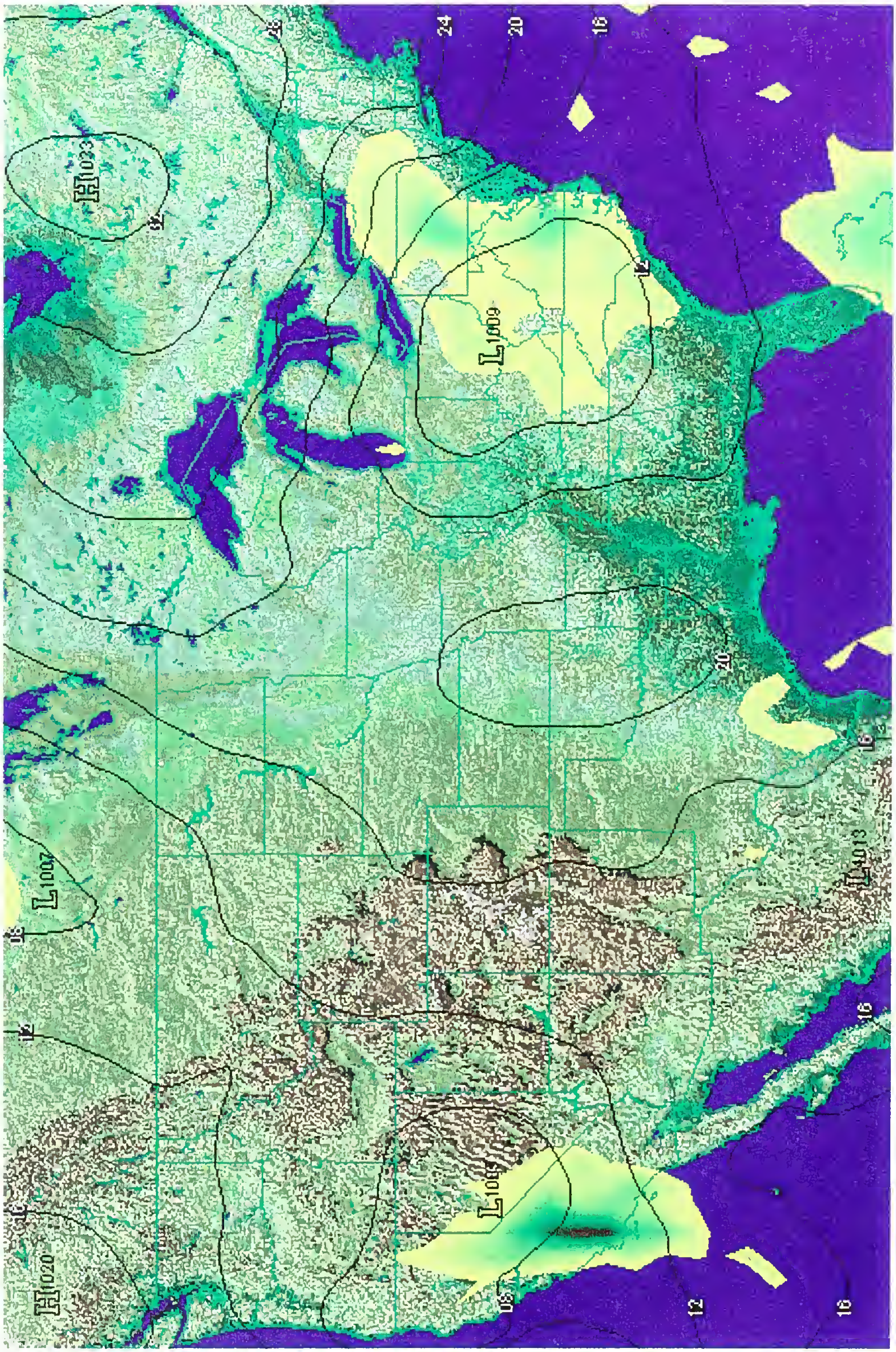


Figure 22. JMV 3.2 with rendered terrain and high resolution coastlines installed. NOGAPS Surface Pressure and 12 Hour precipitation forecasts co-displayed on a synoptic scale.

V. OBTAINING, DEVELOPING, AND DISPLAYING IN-SITU IMAGERY

The ongoing expansion of the internet has contributed to accessibility of government, commercial, and private sources of high resolution (10m or less) environmental imagery (satellite, aerial, radar, webcam) in real time. JMV 3.2 and later versions now support importing locally obtained and developed for use as stand alone or as backgrounds to overlay numeric model fields. This chapter details the process of obtaining, converting, and importing imagery into JMV.

A. DISPLAYING LOCALLY OBTAINED IMAGEREY

1. Hardware and Software Components

Any PC or workstation with access to either the internet or using an external drive (floppy, CD-ROM, Zip, etc.) can import imagery for stand alone display. Images can be obtained in a variety of formats, but must be converted to TIF format for use in JMV. Conversion of imagery may be accomplished using any COTS package (Paint Shop Pro, Adobe Photo Shop, Image Magik, etc.) that allows the user to save as .tif. For a detailed discussion of TIF format requirements see Chapter IV Section C.

2. Procedures for Display

Below are the steps to follow to import and display imagery into JMV.

(a) Display the image in COTS software (this example uses Paint Shop Pro 5.0).

(b) Crop any undesired boundary or border information.

(c) Save the image in .tif format. Ensure there is no compression or if compression is desired use LZW or Packbits.

(d) Geospatial information about images is desirable for importing into JMV. If the latitudinal and longitudinal boundaries of the area for import are known, users can choose to save the file with the following naming convention:

barto_XX.xxNXXX.xxMLXX.xxNXXX.xxM, where XX represents the numerical latitude in degrees, XXX represents the numerical longitude in degrees, xx represents the minutes in decimal form, N represents north latitude or S for south latitude, and M represents E for east longitude or W for west longitude. Note: Use of lower case N, S, E, W is also allowed.

For example consider "barto_35.21n110w5.2s97.15w.tif." This file name specifies an area extending from 35.21 degrees north down to 5.2 degrees south latitude, and from 110.00 degrees west to 97.15 degrees west longitude.

(e) This naming convention is optional. It allows JMV to automatically read in geospatial data instead of requiring the user to enter it into the import interface.

(f) If the precise geospatial location information is not known, the user can utilize the above file format to get the image close to what is desired and then resize it until a best fit is achieved. This process can be quite time consuming but can also be very useful if an image, such as radar data will be periodically imported since the geospatial coordinated need only be determined once.

(g) Now launch JMV, and choose or create an appropriate area which will contain the image to be imported. Then select the "File menu", then "Import tif satellite image". Browse to the image location and select it.

(h) Check to ensure that all the geospatial, naming data, and time information are correct then choose "OK".

(i) The image is now registered under the product selection menu and may be displayed as illustrated in Figure 23.

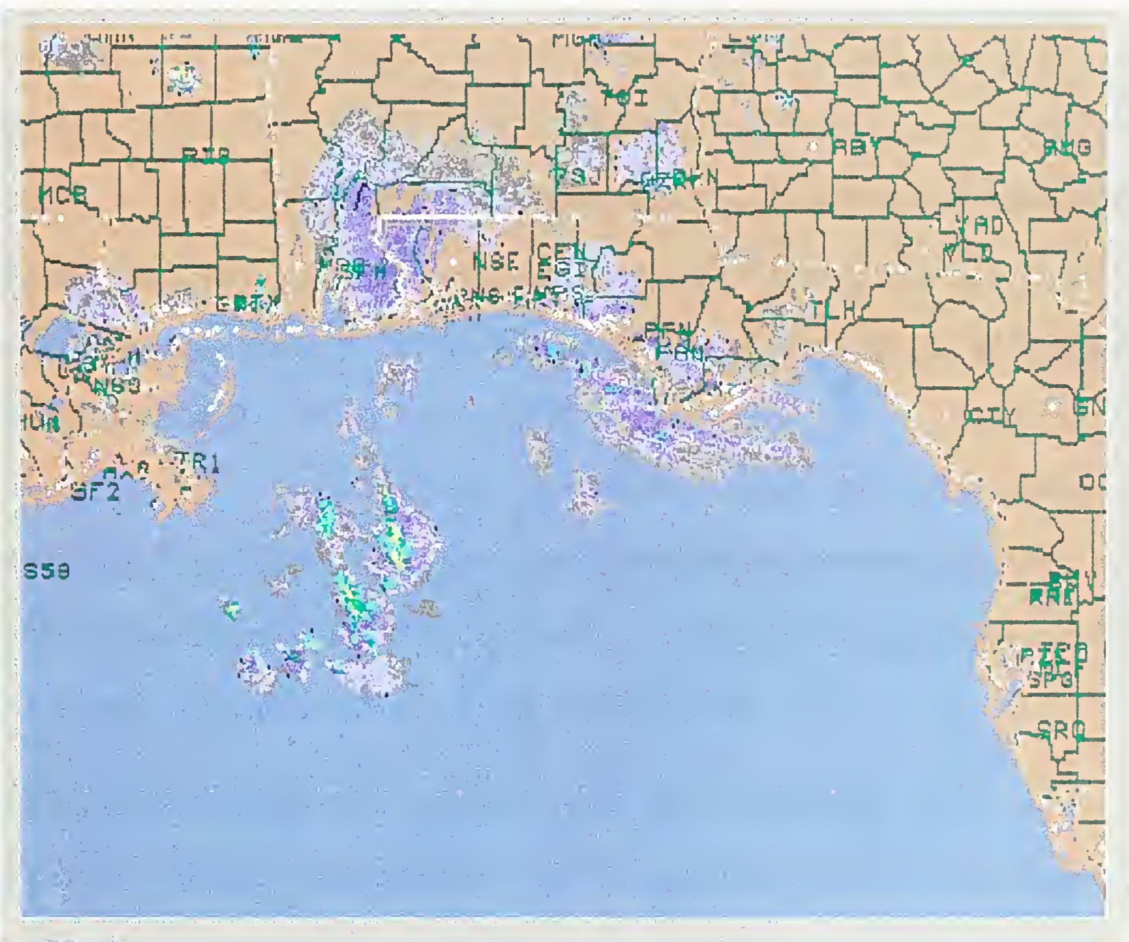


Figure 23: Imported NEXRAD imagery displayed in JMV 3.2.
Source: http://www.rap.ucar.edu/staff/pneilley/NIDS_archives.html.

(j) For areas lacking precise geospatial coordinates in which the user must manually best fit the image, the above process should be repeated until political boundaries or coastlines match up sufficiently to display the information being imported at the desired scale. It is always better to use the highest resolution imagery available to achieve a better quality zoomed image display in JMV.

B. CREATING CUSTOM TOPOGRAPHIC DISPLAYS FROM DIGITAL ELEVATION MODELS

1. Hardware and Software Components

Digital elevation models are derived products in which a database in a recognized format may be manipulated and displayed in a variety of ways. Any PC or workstation running ARCview 3.1 can manufacture digital elevation models. While this is certainly not the only method to manufacture imagery, it does satisfy the minimum requirments established in chapter one. This is also the method used to create the Joint Metoc Viewer Image Database.

2. Procedures for Display

a. 30 Arc Second DEM Data

The GTOPO30 data set covers the globe. The horizontal grid spacing is 30 arc-seconds (0.008333333 degrees latitude or approximately 1 kilometer), resulting in a Digital Elevation Model (DEM) having dimensions of 21,600 rows and 43,200 columns. The horizontal coordinate system is decimal degrees of latitude and longitude

referenced to the World Geodetic System 1984 (WGS84). The vertical units represent elevation in meters above mean sea level. The elevation values range from -407 to 8,752 meters. In the DEM, ocean areas have been masked as "no data" and have been assigned a value of -9999. Low lying coastal areas have an elevation of at least 1 meter; thus, in the event that a user reassigns the ocean value from -9999 to 0, the land boundary portrayal is maintained. Due to the nature of the raster structure of the DEM, small islands in the ocean less than approximately 1 square kilometer are not represented.

Details regarding available coverages and procedures for ordering DEM data sets can be obtained at the USGS Web site: http://edc.usgs.gov/. The GTOPO30 DEM raster data is primarily derived from the DTED Level 1data set and the Digital Chart of the World.

(1) Steps for Downloading and Converting DEM Data. Below are the steps to follow in order to download and convert DEM data.

(a) Create a new folder named gtopo30 to hold downloaded data files.

(b) Download a section from the USGS site: http://edc.usgs.gov/landdaac/gtopo30/gtopo30.html

For the purpose of following along with these instructions download the tile w100n40. This is the second tile down and third tile over from the left. This tile is highlighted in Figure 24, which shows the GTOPO30 globe divided into 33 tiles. Save the downloaded file in the gtopo30 folder.

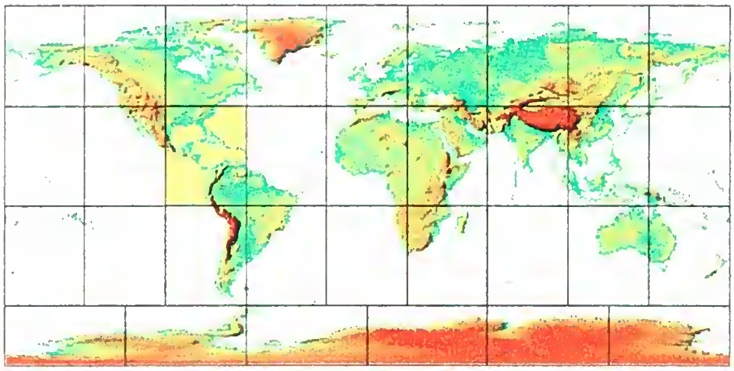


Figure 24. Menu Selection Page with highlighted tile.

(c) These data are compressed. Decompress the w100n40.tar.gz file into the gtopo30 folder using winzip. Ensure that the “tar smart cr/lf” is turned off under the options menu in the program Winzip before extracting this file. There will now be 11 files in the gtopo30 folder, all with different extensions and all beginning with w100n40. Rename the file “w100n40.dem” to “w100n40.bil”. Note: Renaming this file allows the user to import as an image; specifically a Band Interleaved by Line (*.bil) file.

(e) Launch ArcView 3.1. Ensure that Spatial Analyst, 3D Analyst, and JPEG extensions are loaded.

(f) Make a new view and add the w100n40.bil file as an image data source to the view. This is accomplished by pressing the “add theme” button and choosing data source type “Image Data Source”, then highlighting the file and choosing “OK”.

(g) Convert the image to a grid using Menu item "Theme", and the option "Convert to grid".

(h) This grid represents contains information for an area 15 degrees longitude by 25 degrees latitude. Unless working on an extremely powerful workstation, it is now advisable to work with only a portion of this area at any one time. Both a Pentium 333Mhz with 64mb of RAM and an SGI Octane Workstation with 650Mb of RAM were utilized in this thesis. The SGI works smoothly with 5-10 degree by 5-10 degree tiles and the PC works easily with 1-3 degree by 1-3 degree tiles. Resize the working area by using the Menu item “Analysis”, then “Properties”. Set left to –100, right to –95, bottom to 35, and top to 40. Figure 25 shows the resultant display.

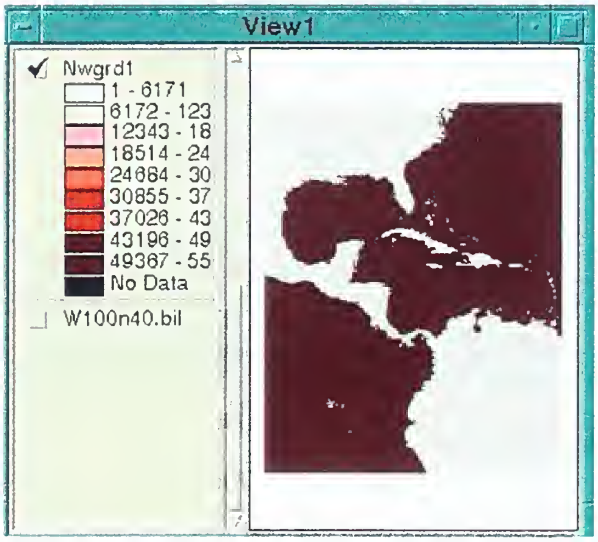


Figure 25. First grid conversion.

(i) Now go to the menu item "Analysis" , "map calculator" . Select the layer Nwgrd1. In the box below and enter the following, then press “Evaluate”:

([Nwgrd1] >= 32768).con([Nwgrd1] - 65536, [Nwgrd1])

The reason for this step is that 32768 is 2 to the 15th power and 65536 is 2 to the 16th power. The GTOPO30 DEM is stored as signed 16-bit data: 1 bit for the sign and 15 bits for the number, hence 2 to the 15th is the maximum value that

could be represented. ArcView interprets the integer data as unsigned, using all 16 bits for the number, thus placing values in the range 0 to 65536. The formula is then needed so that the negative values are properly recognized. Center the image and zoom to a comfortable level.

(j) GTOPO30 data files use –9999's to represent ocean areas. These need to be changed to null. Close the map calculator and then open it again. The new grid theme, named "Map Calculation 1" will now show up on the theme list. Close the old map calculator window. Now go back to the "Analysis" menu and select "Map Calculator" again. Enter the following equation, then press evaluate: ([Map Calculation 1] = -9999).setnull([Map Calculation 1]). Figure 26 shows the resultant display featuring Map Calculation 2.

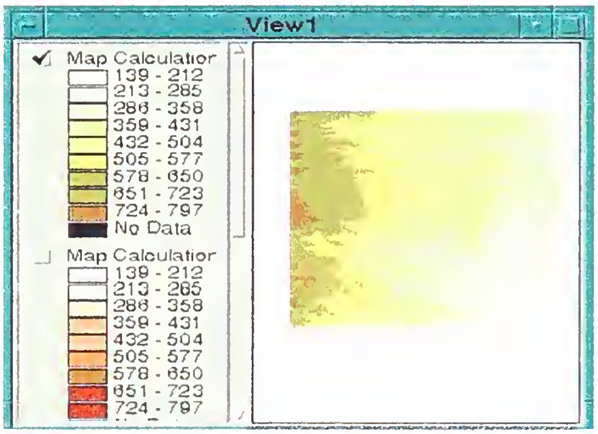


Figure 26. Map Calculation 2 theme turned on.

(k) Map units of this new grid will be in decimal degrees; elevation in meters.

(2) Constructing three Dimensional Projections of GTOPO30 DEM Raster Data (Rendered Perspective Overhead View). This method makes use of Arcview's Hillshading feature and produces an overhead view of a

rendered terrain as shown in Figure 27. The processing steps using ArcView are:

(a) Open the Map Calculator again.

(b) Enter: ([Map Calculation 2]*0.004). This scales the vertical distortion of the resultant rendered image and directly affects shadow effects.

Figure 27. Rendered hillshading.

(c) Then select "Evaluate".

(d) Close the Map Calculator window.

(e) Enable the new theme Map Calculation 3 and make sure it is highlighted.

(f) Now from the "Surface" menu choose "Compute Hillshade". Hillshading is the Arcview command to perform the rendering operation.

(g) Change the altitude setting to 55 and hit "OK". This setting controls the sun's elevation angle shining down on the terrain. A grey shaded relief map (Figure 27) is now ready for export.

(h) Now from the file menu choose "Export" and choose JPEG as the file type. Before saving click on the options button and increase the quality to 100% and the resolution to 144 dots per inch (DPI).

(i) Now use the procedures set forth in the first part of this chapter to import this custom manufactured imagery into JMV.

This chapter explained how to download the Global 30-Arc-Second (GTOPO30) DEM data available from the U.S. Geological Survey's Web site. These data were converted to grid format using Arcview GIS software. The section also explained how to use the Map Calculator in Arcview software to apply several formulas that allowed the software to correctly recognize negative values and modify other aspects of the data. With these adjustments made, the data can be used to render two-dimensional models and export images of these models in formats suitable for use with other programs.

VI. SUMMARY AND RECOMMENDATIONS

A. THESIS SUMMARY

The Joint METOC Viewer has established itself as the Navy's primary numerical product visualization tool. It has unique functionality and is in wide use by the Navy and other DOD agencies. Its ability to overlay numerical charts with remote sensing resources, combined with the added capabilities of time stepping ship and aircraft positions in near real time on a variety of hardware platforms, makes it an indispensable tool for weather and ocean analysis and forecasting.

FNMOC's Joint Metoc Viewer program has a continous internal and external review and revision process. This process seeks fleet input and responds to evolving requirements and technological improvements by upgrading JMV. This thesis worked within the boundaries of this program to identify visualization deficiencies, and to recommend and enact changes and upgrades.

In order to improve the capabilities of JMV, this thesis added the capabilities listed below:

- Integrated high-resolution coastlines and polygon drawing fills.
- Updated geo-political boundaries and created a method for future seamless NIMA updates by converting software to allow for use instant integration of NIMA datasets.
- Integrated scrolling background topographic and bathymetric databases.
- Integrated high-resolution inland waters globally.

- Integrated contourable background topographic and bathymetric databases with user defined levels.
- Integrated and expanded color fill capability for "on-the-fly" drawing of background fields.
- Designed and integrated background image import interface.
- Designed and integrated global 1 km terrain database interface.

B. RECOMMENDATIONS FOR FUTURE IMPROVEMENTS

1. Better Integration Of Geostationary Satellite Resources

Current methods for importing an animating geostationary satellite data such as GOES, METEOSAT and GMS satellite products require the operator to use geographic areas specified by the data source origination point. This methodology breaks with the fundamental strength of the JMV/METCAST system; the ability of users to define areas of interest and product requirements with the ability of getting information for individual mission requirements.

GOES imagery should be tiled, much the same ways as the JMV GIS-Image Data Base is structured and parsed down on the server side as time stamped products and delivered for user defined areas as they are created.

2. Configuring JMV For Exporting More (Warfighter Defined) Data Types… (.Shp, Tda, Etc.)

Current capabilities feature screen exports in .bmp, .tif, .gif, and .jpg formats. Additionally, on screen data can be exported to ASCII text files for ingesting

into other programs.

Since JMV/METCAST is the principal method for delivering numeric product information to forecasters supporting warfighters, additional export capabilities should be designed that allows for the direct input of numeric product output into tactical decision aids and advanced GIS tools such as ArcInfo, ArcView and Arc Explorer. These tools are employed by fleet staff planners (CINCSOC, JIATF), the National Imagery and Mapping Agency, Naval Oceanographic Office, and the Naval Post Graduate School and are used by at least 300,000 other agencies globally (ESRI, 2000).

C. OPERATIONAL IMPLEMENTATION

All of the features described in this thesis with the exception of the JMV GIS-IDB have been operationally tested and distributed to the fleet via SPAWAR's on CD-ROM. The JMV GIS-IDB is scheduled for release on the program CD-ROM in September 2000 following the next round of operational testing. This thesis has significantly extended JMV's capabilities to assist the METOC forecasters provide improved meteorological and oceanographic analyses and forecasts to the fleet. These new capabilities allow the METOC forecaster to more effectively forecast critical mesoscale phenomena to improve fleet support.

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